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Development of physical disability in older adults

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Abstract

Demographers expect the number of older persons to double to 86.7 million— or to 20.6% of the US population— by the year 2050. As has occurred over the past decade, the health care costs associated with older age are expected to steadily increase approximately 2% per year causing both a public health and personal burden. A key component to reducing health care costs and maintaining well-being in older persons is preserving physical function throughout the lifespan. The challenge to this objective is to combat the origin of the loss of physical function through treatment of chronic disease conditions. Another approach is to enhance physical function despite the occurrence of comorbid conditions through enhancement of the neuromuscular system. The neuromuscular system provides the necessary components for all locomotion, and is thus a logical choice for preventative therapies to target. This article will give a general overview of the models and risk factors that explain the development of physical disability.

Keywords

Aging; disability; activity limitations; physical ability; economic burden

Introduction

In 2006 there were 37.3 million adults over the age of 65 years living in the United States [1]. Demographers expect the number of older persons to double to 86.7 million— or to 20.6% of the US population— by the year 2050. This surge in growth of the aging population has even prompted the Institute on Medicine to develop specific literature focused on retooling medical resources for an aging America [2] to cope with the 42% or 15.6 million who report having one or more limitations performing daily tasks (e.g. walking 2–3 blocks, transferring from the chair) that are essential for maintaining independence in the community [1]. Approximately 22% of women and 15% of men report that they are dependent on caregivers to successfully perform these same tasks [3].

Disability rates among Americans are closely followed through National Health Statistics and as such public health professionals can predict future care. Undoubtedly, the impending population change will increase the absolute number of individuals having activity limitations [4–6]. However, improvements in education and socioeconomic status have helped decrease disability prevalence rates by 0.4 to 2.7% per year [4, 6–8]. This has also translated to a concomitant 10-year reduction in assisted living care in adults 65 years and older [1]. While these trends have persisted for the past decade, the most recent data from the National Health and Nutrition Examination Surveys suggests an opposing view where individuals in the seventh decade of life have higher rates of severe mobility disability compared to their predecessors evaluated over a decade ago. At the same time, the disability

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rates for adults aged seventy and eighty years have not changed [9]. The discrepancy is thought to be related to the underestimation of the impact of increasing ethnic and obese individuals who contribute disproportionally to higher disability rates [10]. Consequently, the more recent cohort of adults reaching older adulthood is racially diverse and exposed to being obese and overweight for a longer period of time. Ever-changing demographic profiles hold an uncertain future for = disability rates, which have tended to decrease over the past decade. Therefore, continued research on preventive and coping strategies to combat physical disability remain critical.

In 2004, the average health care cost of adults over the age of 65 years ranged from $10,000 to $16,000 per year and this rate has increased over the past 10 years[11]. As expected, individuals with more chronic conditions incurred an increased annual health care cost of $20,000 per year, and this value rises to $52,000 per year for individuals in long-term care facilities. In contrast, individuals of the same age who remain free of chronic disease conditions and are community-dwelling spend between $4,000 and $10,000 per year in health care costs. These data clearly demonstrate a significant public health burden for chronic disease conditions and the impact of requiring assistance in daily care needs. As such, personal well-being and significant health care savings can be incurred when individuals remain functionally independent throughout in life.

While much of the content for this contribution in Current Aging Science is focused on the age-related changes in function, biology and physiology of the neuromuscular system it is important to build a rationale for such knowledge. To this end, the models used to characterize the development of physical disability and the most common risk factors that contribute to developing physical disability are presented. This information will serve as a backdrop for information presented in articles that follow.

Models of the development of disability

The development of disability involves a balance between an individual's inherent physical function and the environmental demands they undertake. Approximately half of the end stage of disability in self-care tasks results from a progressive loss of function, whereas the remainder occurs through a catastrophic event [12]. Several conceptual models have been created to capture the development of disability originating as a progressive loss of function. This section will provide a brief, but contemporary review of the development of disability.

Saad Nagi developed the core characteristics for one of the most popular disability models [13]. The model has four central components: active pathology, impairment, functional limitation and disability (see Figure 1 for an example of the Nagi scheme) with expansions made by Verbrugge & Jette and the Institute on Medicine (IoM) [14]. The model has been accepted by both medical and sociological disciplines and for over a decade was preferred by the IoM [15]. The initiating phase of pathology is somewhat deceiving because it suggests a traditional disease origin, which often manifest into clinically defined impairments. However, the true intention is that any inherent biological abnormality can serve to begin the disablement process. For the case of the neuromuscular system, an example would be inappropriate calcium handling at the sarcoplasmic reticulum. This biological problem might lead to a significant impairment with muscle contraction that imposes consequences on physical functioning. At the next stage, a functional limitation occurs when the severity of impairment results in restrictions in performing fundamental physical actions. These indicate all the abilities needed to perform *purposeful* work. As an example, impaired muscle force production is considered a functional limitation, but not a physical disability because it involves an inherent property without reference to a situational environment [14]. As such, the development of a disability is largely a social process where the pathology, impairment and limitation culminate in the loss or minimization of the ability to fill expected social roles. The Nagi scheme provides a balanced model acceptable to medical and sociological disciplines and is popular among researchers across a variety of backgrounds due to the conceptual clarity and measurement feasibility to test hypotheses.

The onset of disability occurs with frequent transitions between independent and dependent states. Support for this is provided by an elegant serious of studies led by Thomas Gill and colleagues who assessed mobility disability every month for 5 years and demonstrated that older persons frequently transition from intermittent to mobility limitation (at a rate of 68.6 per 1000 person-months) [16–19]. However, transitioning occurs less often from no disability to intermittent disability (34.7 per 1000 person-months), intermittent to continuous disability (52 per 1000 person-months), and continuous to intermittent disability (35.4 per 1000 person-months). Additional data demonstrate that individuals have a 40% recovery rate after being disabled for up to 3 months, but only one-third were able to recover for more than 6 months [19]. These results suggest that older persons have frequent transitions between states of independence and disability opening several opportunities to restore and maintain independence.

Despite the high variability of disability, a growing literature suggests that a pre-clinical (or sub-clinical) stage of disability resides between the onset of functional limitation and outright disability in the Nagi scheme [20–22]. Pre-clinical disability has been referred to as an early warning system in the disablement process and is analogous to sub-clinical disease. Selecting to perform everyday tasks less often and compensating for those tasks still being performed characterize it. The slow progressive loss in physical function and development of disability with an intermittent pre-clinical stage of disability is illustrated in Figure 2. This figure also recognizes that changes in physical capacity are linked to the variable transitions in disability over the age span [18, 23]. The evidence for a pre-clinical stage of disability was first demonstrated by Fried and coworkers who implemented a battery of questions to address signs of pre-clinical disability in the Women's Health and Aging Study II (WHAS) [20]. The questions were presented in a manner to first ask whether the person had difficulty performing any of the 27 tasks from the standardized questionnaire used in the National Health Interview Survey. To identify early declines, the investigators then asked whether individuals had modified or had changed the frequency with which they performed the task. Individuals who had modified or changed the frequency yet reported no difficulty were labeled as pre-clinically disabled. When compared to individuals who had no difficulty and no modification of tasks, pre-clinically disabled adults were 3.8 times more likely to report difficulty walking ½ mile and climbing ten stairs 18-months later [24]. This association was over double that found with objective measures such as walking and stair climbing speed, and as such highlights the powerful predictive nature of pre-clinical disability. These results were followed with a similar approach to determine whether disease, impairments and performance measures in pre-clinical disability were intermediary of high function and outright disability [24]. Individuals who reported no difficulty yet changed the way they walked a ½ mile or climbed ten steps had greater muscle strength, balance, physical function, flexibility and gait speed than individuals who reported outright difficulty. Interestingly though, these same measures were better in high functioning than pre-clinically disabled individuals. Similar results were found with disease status where a trend for increasing prevalence of osteoarthritis was demonstrated across high functioning, pre-clinically disabled and outright disabled individuals. These data suggest that self-report of modification of everyday tasks identifies a stage of function or disease intermediary of high function and outright disability.

While the Nagi scheme remains widely used it has become overshadowed by the recent adoption of the World Health Organization's International Classification of Functioning

(ICF) and adoption by the IoM [25]. The consensus recommendation for use of the ICF was prompted to more fully recognize the contributors to functioning and onset of disability by highlighting the complexity of its origin and the variety of elements that lead to its progression. For example, the Nagi scheme does not include factors such as psychological and environmental issues – rather these are implied in the model. Therefore, the most contemporary view of disability provided by the ICF is a holistic attempt to build an organizational scheme to more completely capture the complexity of disability (a model with the additional role of neuromuscular function is provided in Figure 3) [26]. This model replaces the World Health Organization's International Classification of Disease that had three central themes that included impairment and disability evolving to handicap [27]. The model has also replaced the Nagi scheme as the accepted model for the IoM. The ICF divides the origin of functioning into body functions/structures and activities/participation. It then classifies contextual factors into environmental and personal that contribute to the progression of disability and blankets the background of an individual's life situation. Using these components, the ICF maps the different constructs and domains in multi-perspective processes that interact upon each other to simulate realistic scenarios. Of interest to the current contribution is the strong emphasis that the ICF places on the execution of a task, which has a strong neuromuscular component through mobility and self-care movements. Regarding neuromuscular function, activity limitations might arise through impairments in the planning and manifestation of movement at the cortex, its transmission through the spinal cord, as well as its response at the muscle level— ranging from excitation-contraction coupling to metabolic and biochemical characteristics of the skeletal muscle fibers.

Risk factors for disability

The maintenance of physical function has been linked to fending off cellular and molecular damage and delaying illness, disease, and disability that keeps an organism functioning optimally for the longest period of time [28]. To this end, the loss in physical function can be impacted through social influences (gender, socioeconomic status, race, age and cultural context) [29], individual traits of well-being (psychosocial and behavioral) [30], biological processes (inflammatory responses, oxidative damage to cells and hormonal changes) [31] and environmental adversities (neighborhood characteristics and air quality) [32]. Information on socioeconomic and psychosocial factors will not be provided but exhaustive reviews of these factors can be found in the following references [33–37]

Age

It is clear that the loss in physical function is inevitable, but the effects of age are highly individual and age alone is a poor index of physical function [38]. Many older adults successfully age without disability (e.g. Jack LaLanne, Bette Davis, Paul Newman). However, while age alone may be a poor index of physiological function, it is associated with increased prevalence of disease conditions that are impossible to ignore as a strong contributor to occurrence of disability.

Rates of physical limitations in daily activities remain constant up to the age of 45 years, but the trend takes several parabolic shifts upward in later adulthood. The first occurs at a fairly early age where the proportion of individuals who report limitations in usual activities increases from 6.5 to 16.9% [39]. At the age of 65 years, the trend shifts upward to 26.9% and again to 45.3% at age 75 years and older. Fifty-five percent of women and 38% of men over 85 years older report being unable to perform a mobility task such as: walking, stooping/kneeling, writing and lifting 10 lbs [40]. The physical limitations noted above follow an identical pattern with chronic disease conditions and highlights the difficulty in separating the effect of biological age and disease [39].

Disease

The loss in physical function and increase in physical disability with age is tightly coupled with the occurrence of one or multiple diseases. These include hypertension (53.3% of the population 65+ years), osteoarthritis (49%), cardiovascular disease (CVD = 30.9%), cancer (21.1%), lung dysfunction (20.6%), diabetes (18%) and stroke (9.3%). The top two conditions that contribute to this burden are cardiovascular disease and osteoarthritis, which combine to affect almost 80% of the adults over the age of 65 years [1]. While the prevalence of these conditions would suggest a somber scenario for older adults, the disability impact that these conditions is not equivalent to their prevalence. For example, conditions such as hearing and vision impairments or osteoporosis that leads to bone fracture are less prevalent, but have considerable impact on the occurrence of disability [41, 42]. Cardiovascular disease, however, has both a large prevalence and impact on poor physical function as it is associated with a 6.5-year loss of having intact physical and cognitive function [43]. Osteoarthritis is the second most prevalent pathology in older adults with the impact on physical disability ranking lower than CVD, senses impairment, and diabetes [44]. Despite the fact that osteoarthritis impairs integrity of the cartilage, increases perceived pain and seems to have repercussions for poor muscle strength [45, 46], osteoarthritic individuals are resilient because they use less personal assistance than other disabled individuals [47].

The degree to whether disease conditions directly lead to physical limitations can also be evaluated through their treatment. For osteoarthritis, surgical intervention has a major benefit on long-term physical function in patients who are typically in the lowest half of physical function among the US population [48, 49]. Prospective studies following patients undergoing hip or knee total arthroplasty show a complete restoration of physical function up to 12 months following surgery [48, 49] with a slight decline 3 years post-surgery [50]. In another example the Systolic Hypertension for the Elderly Program trial (SHEP) demonstrated a significant reduction in cardiovascular events while at the same time reducing the incidence of physical disability among participants randomized to anti-hypertensive medications [51]. Such findings suggest a strong inter- relationship between chronic disease and physical disability through its reversal with disease treatment.

Obesity

Recent estimates indicate that 35% of older adults are obese [52], and a growing literature suggests that obesity in older adults is associated with greater risk of physical disability. Obesity is associated with heightened risk for physical disabilities in older persons, as well as earlier onset of severe disability [53–55]. Using NHANES data, Alley and Chang found that obese older adults had 1.78 greater odds of functional impairment than normal-weight adults. Additionally, obese older adults had a 2-fold greater odds of impairments in basic activities of daily living compared to normal weight older adults. Interestingly, obese individuals were also found to have a 43% increase in impairments over a 10 year time frame, while normal weight older adults demonstrated no change. Additional work by Peeters and coworkers demonstrated that obese older adults have approximately 5 fewer years free of being disabled in basic daily activities [54] than normal weight adults. Much of this additional disability can be attributed to increased risk of chronic conditions closely associated with obesity as demonstrated with an elevated risk of diabetes [56], cardiovascular disease [57, 58], osteoarthritis [59], chronic heart failure [60], hypertension [56], and some cancers [61]. For obese individuals, physical disability seems to be impacted primarily through osteoarthritis [62], which is 2.6 times more likely than normal weight individuals [59]. Additionally, comorbidity (2 or more conditions) is common among obese adults with 70–80% prevalence compared with 40% in normal weight adults [63]. This additional comorbidity with obesity would be considered a strong contributor to the high rates of disability found in older obese individuals [64].

Physical performance

Performance of a physical task is closely associated with the concept of functional limitations on the Nagi pathway to disablement. Over the past two decades a wide variety of performance batteries have been developed that incorporate objective parameters such as the speed or distance traveled for a particular physical task [65–69]. The most well-known physical performance test is the Short Physical Performance Battery (SPPB) developed by scientists at the National Institute on Aging [70]. The battery includes measures of gait speed, chair rise speed and balance that are scored according to a nationally representative sample from the Established Populations for Epidemiologic Studies of the Elderly. Performance scores on the SPPB are highly predictive of health conditions in the elderly that include: hospitalization, nursing home admission, mobility limitation, and dependence in basic care needs and mortality [66, 68, 71]. For example, independent older persons who score in the lowest half of performance scores are 5 times more likely to develop disabilities in basic care needs 4 years later [67]. Additionally, approximately 60% of individuals who score in the lowest third of SPPB score develop mobility disability while less than 10% develop the same condition 4 years later. The ability to successfully perform SPPB tasks originates in part to high levels of muscle strength that will be discussed in the next section [72, 73].

Muscle mass and strength

The neuromuscular system plays a key role in providing the necessary backbone to the performance of mobility and daily movements that are essential for maintaining physical independence. While disease conditions are the main element in the occurrence of physical disability in older adults, the variability in the loss of physical function and onset of activity limitations can be partially explained by the characteristic changes of the neuromuscular system with aging [74, 75]. Data on the loss in muscle characteristics with aging has rapidly accumulated over the past 30 years providing scientists a better understanding about the degree to which muscle properties are involved in disabling conditions.

Muscle tissue acts as the body’s major reserve of readily available amino acids and is associated with morbidity and mortality in cachetic conditions (HIV, cancer and congestive heart failure) [76]. Resembling the findings in disease conditions, lower levels of muscle mass were initially found to be associated with lower physical performance among community dwelling aging adults [77]. As such, the amount of muscle mass became a logical first phase target for improving physical function among older persons [78–81]. The initial data provided the rationale to construct large-scale longitudinal studies to understand the degree to which muscle characteristics and total body composition were associated with the loss in physical function [82]. Despite a strong inclination for lower muscle mass to be the major culprit in predicting activity limitations [78, 83], results from these longitudinal studies portrayed a different view. Instead, the data suggested that having greater amounts of muscle mass did not necessarily protect older adults from the onset of activity limitations, but muscle strength regardless of the amount of mass was the major factors [75, 84]. In these studies, older adults lost muscle mass at a rate of 1% per year, but despite this loss, a quarter of the subjects were able to preserve in their muscle strength [85, 86]. Additionally, over half the cohort lost muscle strength at triple the rate of their loss in muscle mass.

Muscle strength is a strong predictor of severe mobility limitation, poor mobility performance and mortality. Specifically, the data suggest that older adults with low levels muscle strength have 2.6 fold greater risk of severe mobility limitation, 4.3 fold greater risk for slow gait speed and 2.1 fold greater risk of mortality compared to older adults with high muscle strength [74]. Over the past decade the influence of muscle mass on the incidence of activity limitations among older persons has not yielded expected associations causing scientists to look into what other factors control muscle strength, namely the neural and biochemical kinetics that control muscle contraction.

There has been substantially less research on how other factors apart from muscle mass, strength and adipose infiltration contribute to the loss in physical function with age. Most recently, peripheral nerve function measured as nerve conduction amplitude at the calf and sensory motor detection assessed through insensitivity to vibration stimuli at the great toe of the foot are beginning to be used in epidemiological studies to understand the association with physical performance of older adults [87]. This work found that both efferent and afferent properties of the peripheral nerve were positively associated with muscle strength. Specifically, individuals who were sensitive to vibratory stimuli or had high peripheral nerve conduction amplitude demonstrated a high level of muscle strength. These data suggest that the quality of neural properties may be an important factor in preserving muscle strength. The findings are supportive of previous research in diabetics [88], but there is only one additional replicate study in non-diabetics [89]. Considering that these studies were also performed as a cross-sectional design the results provide an unclear cause and effect relationship. Despite these limitations, this growing literature suggests potential interventions that target peripheral nerve function for restoration of the loss in muscle strength.

Conclusions

The intent of this review paper was to describe the development and risk factors for physical disability in older persons. The development of disability is complex process involving biological and disease conditions that are uniquely integrated into a social and environmental context. Disability is not a concrete state, but older persons frequently transition from being independent to dependent or vice-versa. Individual and combinations of disease conditions are the strongest risk factors for the development of physical disability with more recent research suggesting that physical performance and muscle characteristics are also involved. Obesity along with its corresponding increase in disease conditions is emerging as an important and highly prevalent risk factor for physical disability. The numerous risk factors for physical disability provide for opportunities to intervene at several levels.

Gerontologists have constructed models on which understand the development of disability and the neuromuscular system can have an integral role. In this regard, the research on the neuromuscular system for the past decade has primarily focused on the role and regulation of muscle mass with results demonstrating a minor role in the incidence of poor physical function. However, new science is beginning to explore other pathways involved in modulation of muscle strength. With this research, it is expected that new treatments targeted to neuromuscular health will be discovered.

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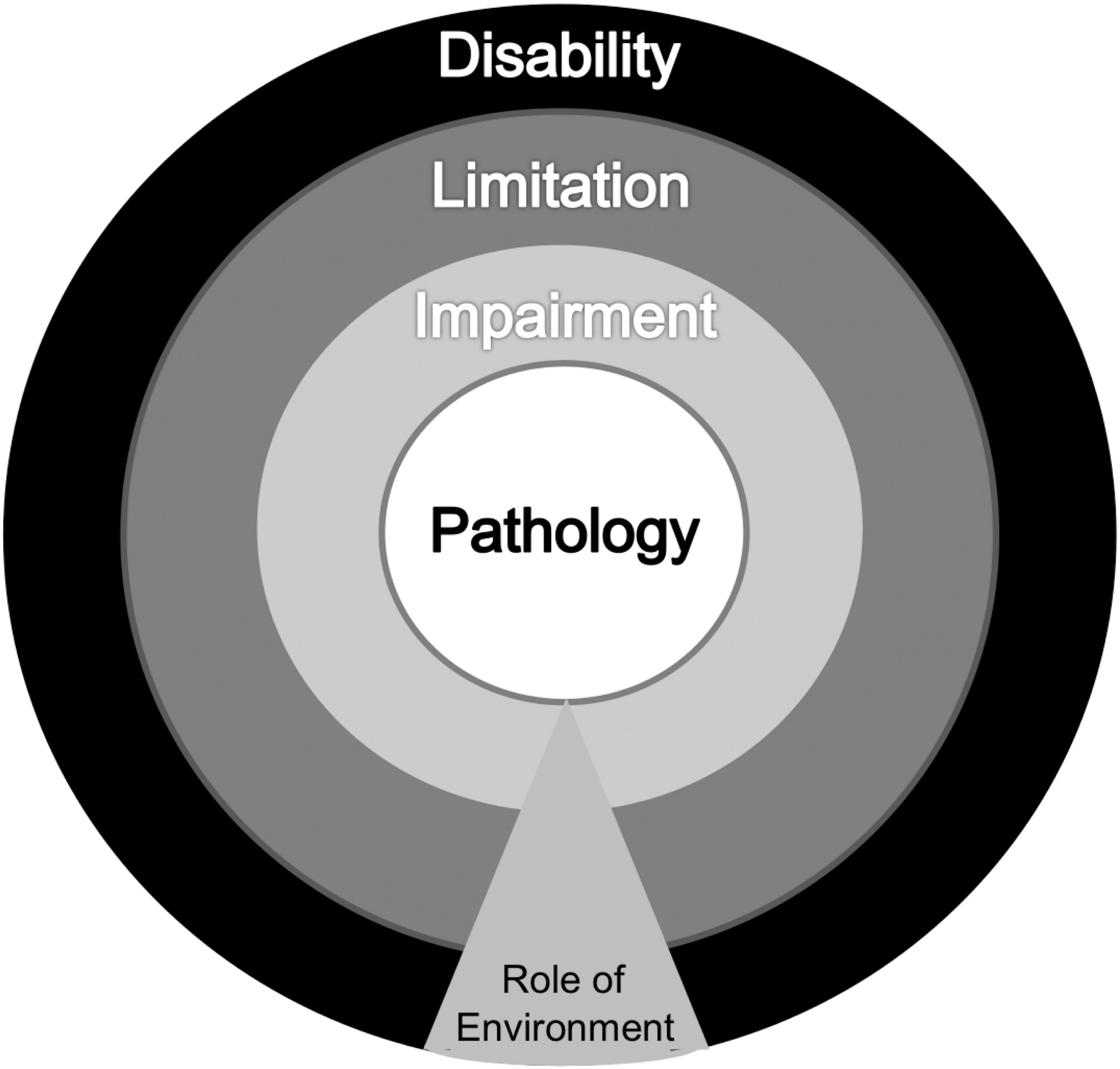

Figure 1.
The disablement process as a function of the expanding role of environment.

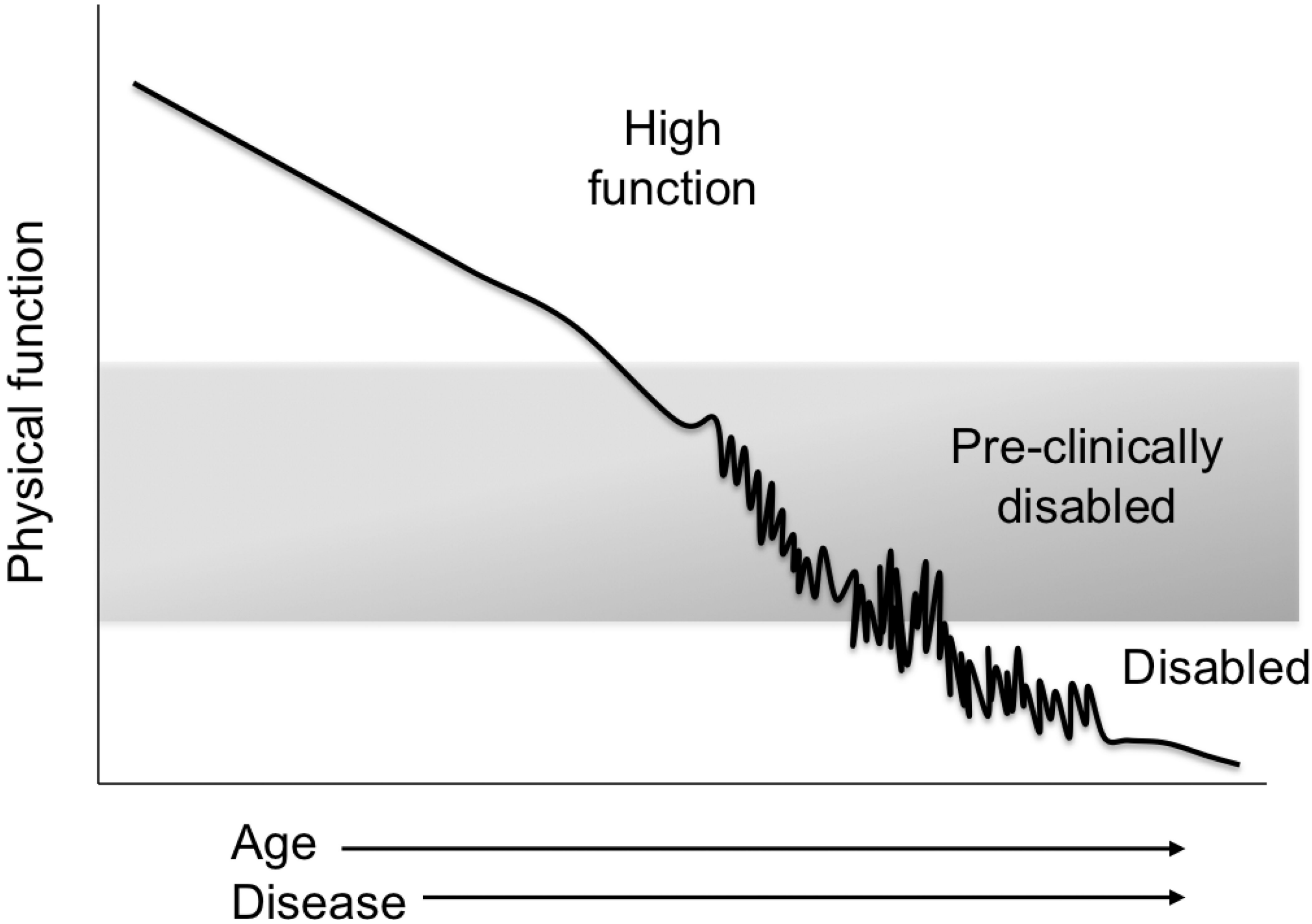

Figure 2.
Progression of physical function with age and disease status. Loss in physical function and progression to physical disability is a highly variable process where individuals experience frequent episodes of decline and recovery. The variability at the end of the spectrum is reduced because recovery in old age occurs irregularly.

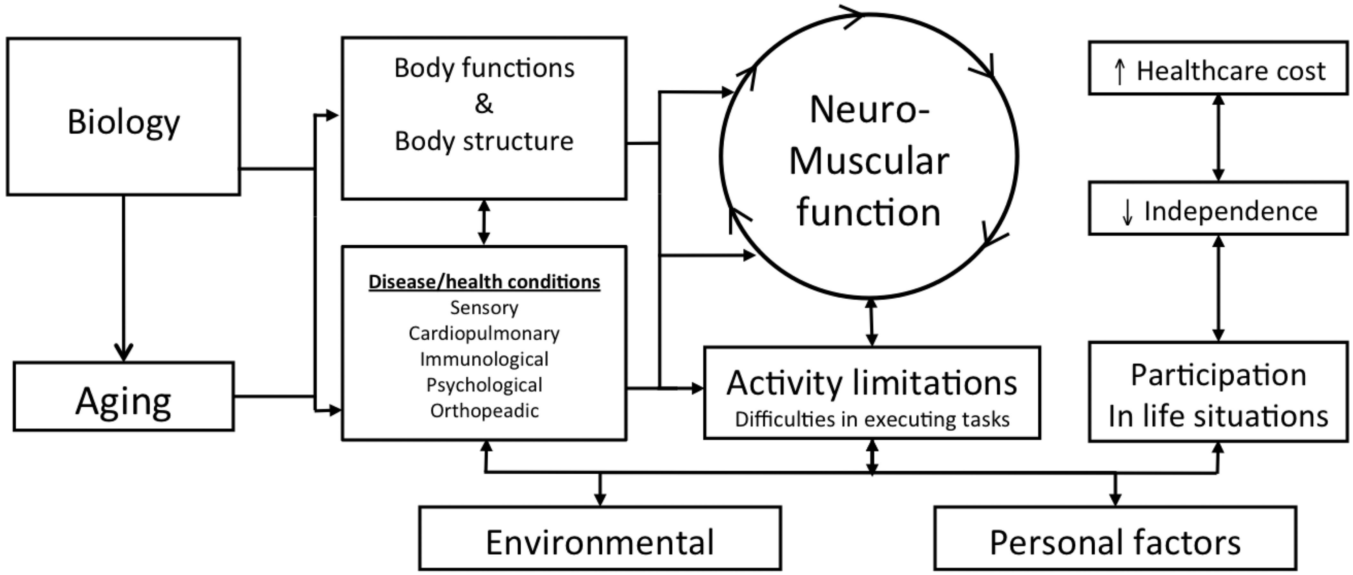

Figure 3.
Mechanisms and consequences of activity limitations (i.e. physical limitation & disability) placed within the context of the International Classification of Function (ICF) model developed by the World Health Organization. Neuromuscular function is influenced by a host of diseases, cell biology and aging, that manifest through direct or indirect physiological consequences. Subsequently the condition contributes to a number of personal, familial, and societal consequences. Impairments in neuromuscular function may mediate activity limitations through influences on muscle strength. Participation in life situations is the ICF language used to describe the ability of individuals to participate in daily societal activities such as going to the grocery store, attending family events, or traveling.